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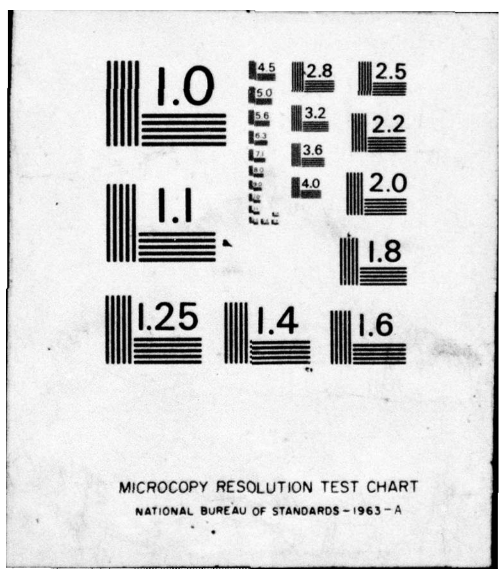
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US ARMY TEST & EVALUATION COMMAND

FINAL REPORT OF TEST

MILITARY POTENTIAL TEST

OF THE

HELICOPTER ROTOR BLADE EROSION-PREVENTIVE KITS

DA PROJECT NO. 1R179191-D-684

USATECOM PROJECT NO. 4-3-5220-02

10 JUN 1965

US ARMY
AVIATION TEST BOARD
FORT RUCKER, ALABAMA

DEPARTMENT OF THE ARMY
UNITED STATES ARMY AVIATION TEST BOARD
Fort Rucker, Alabama 36362

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ABSTRACT

The Polyurethane, Neoprene, and Estane shoes were applied to the main rotor blades of UH-1 Helicopters operated at Fort Benning, Fort Rucker, and "Operation Desert Strike."

Requirements for installation of the three types of shoes were such that it could not be accomplished at the organizational maintenance category. The Estane shoe could be applied at the direct-support category and the other two types required general-support maintenance facilities. Flight in rain damaged all three types of shoes, whereas they withstood successfully the effects of sand and dust.

It was concluded that, because of the effects of rain on the shoes, none of the kits possess military potential for use in tropic and temperate areas; however, data indicate that they possess military potential in arid areas. None of the kits is suitable for installation or removal at the organizational level, and the Estane kit is the most suitable for installation or removal at the direct-support maintenance category.

It was recommended that research continue until suitable material is found for the elimination of the rotor-blade erosive problems in all environments; that further consideration be given to the Estane kit for Army use only in desert areas provided that installation is accomplished at the direct-support maintenance category and that helicopters with the shoes installed are restricted from flying in rain; and that further testing be conducted under controlled conditions to develop specific data relative to the life expectancy of the Estane shoes in an arid environment.

DEPARTMENT OF THE ARMY
UNITED STATES ARMY AVIATION TEST BOARD
Fort Rucker, Alabama 36362

FINAL REPORT OF TEST

MILITARY POTENTIAL TEST

OF THE

HELICOPTER ROTOR BLADE EROSION-PREVENTIVE KITS

USATECOM PROJECT NO. 4-3-5220-02

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SECTION 1 - GENERAL

1.1. REFERENCES.

a. Letter, AMCPM-IR-T, Headquarters, US Army Materiel Command, Washington, D. C., 26 February 1964, subject: "Evaluation of Rotor Blade Erosion Preventive Kits," with 1st Indorsement, AMSTE-BG, Headquarters, US Army Test and Evaluation Command, 26 February 1964.

b. Message, AMCPM-IR-3-1074, Headquarters, US Army Materiel Command, 12 March 1964, subject: "Installation of Rotor Blade Erosion Preventive Kits."

c. Message, AMSTE-BG-TT4180, Headquarters, US Army Test and Evaluation Command, 16 March 1964, subject: "Retransmittal of Message 3-1074 AMCPM-IR, subject: 'Installation of Rotor Blade Erosion Preventive Kits.'"

d. Plan of Test, USATECOM Project No. 4-3-5220-02, DA Project No. 1R179191-D-684, "Military Potential Testing of Helicopter Rotor Blade Erosion Preventive Kits," US Army Aviation Test Board, 20 April 1964.

e. Message, AMCPM-IR 4-1193, Headquarters, US Army Materiel Command, 24 April 1964, subject: "Kit Installation Demonstration."

f. Letter, STEBG-LE, US Army Aviation Test Board, 6 July 1964, subject: "Rotor Blade Erosion Preventive Kits, USATECOM Project No. 4-3-5220-02."

g. Message, AMCPM-IR-T 8-1126, Headquarters, US Army Materiel Command, 20 August 1964, subject: "Rotor Blade Erosion Protective Kit."

h. Letter, STEBG-LE, US Army Aviation Test Board, 15 September 1964, subject: "Rotor Blade Erosion Preventive Kits, USATECOM Project No. 4-3-5220-02."

i. Message, APG 20382, 10 December 1964, subject: "Arctic Testing of Rotor Blade Preventive Kits."

1.2. **AUTHORITY.**

1.2.1. Directive.

Letter, AMCPM-IR-T, US Army Materiel Command, 26 February 1964, subject: "Evaluation of Rotor Blade Erosion Preventive Kits," with 1st Indorsement.

1.2.2. Purpose.

To determine the military potential and operational suitability of the helicopter rotor blade erosion preventive kits.

1.3. **OBJECTIVES.**

To determine with respect to each kit:

a. Physical characteristics

b. Installation requirements

c. The effect of the kit installation on helicopter flight characteristics

d. Resistance capability against erosive agents (sand, rain, and dust)

e. Capability to withstand environmental extremes

f. Maintenance requirements

g. Ability of the shoes to adhere to the rotor blades

1.4. **RESPONSIBILITIES.**

1.4.1. The US Army Aviation Test Board (USAAVNTBD) was responsible for test plan preparation, test supervision, and test reporting (letter report).

1.4.2. The US Army Arctic Test Board was responsible for testing one kit of each type; however, this requirement was canceled by reference i.

1.5. DESCRIPTION OF MATERIEL.

The test items are protective covers for the leading edge of helicopter main rotor blades.

1.5.1. The Polyurethane kit consists of two Polyurethane blade shoes, adhesives, primers, and cleaning materials. The Polyurethane shoes are constructed of an amber-colored, soft, pliable material. The bonding process consists of thoroughly cleaning the leading edges of the blades with acetone, sandpaper, and cloth; rewashing with acetone; and application of the adhesive and shoes.

1.5.2. The Estane kit consists of two Estane blade shoes, primer, adhesive, sealer, and cleaning materials. The Estane shoes are constructed of a black, soft, pliable material (similar to rubber) with an internally woven cord ply. The bonding process consists of thoroughly cleaning the rotor blade with methyl ethyl ketone or acetone and application of the adhesive and the shoes.

1.5.3. The Neoprene kit consists of two Neoprene blade shoes, primers, adhesive, sealers, and cleaning materials. The Neoprene shoes are constructed of a black, soft, pliable material (similar to rubber). The bonding process consists of thoroughly cleaning the blades with methyl ethyl ketone or acetone and application of primer, adhesive, and the shoes.

1.6. BACKGROUND.

1.6.1. A critical need exists for a system to protect helicopter rotor blades against excessive deterioration from the effects of sand, rain, and dust. Experience has shown that UH-1( ) helicopters operating in dusty and/or sandy environments frequently require rotor blade replacement after 300 hours of operation or less. Blades at Fort Benning, Georgia, have been condemned because of erosion with as little as 165 hours flying time. UH-1D rotor blades are normally retired after 1000 hours of operation, and UH-1B blades, after 1100 hours.

1.6.2. In 1962, USATRECOM negotiated a contract (DA44-177-TC-836) for a research program to investigate possible erosion-resistant materials and for the development of a blade-protection system.

1.6.3. In 1961, the USAAVNTBD informally evaluated helicopter blade erosion preventive materials, which were found to be generally inadequate.

In 1962, during the service test of the UH-1D, the USAAVNTBD tested two Neoprene kits with shoe thicknesses of 0.065 inch and 0.095 inch. These shoes demonstrated considerable potential. As a result of these findings, the Iroquois Project Manager contracted with the manufacturer for two types of kits (Estane and Neoprene) to be included in this evaluation. The third type, Polyurethane, was furnished by USATRECOM.

1.7. FINDINGS.

1.7.1. Physical Characteristics.

There were no significant differences in the physical characteristics of the three kits.

1.7.2. Installation Requirements.

1.7.2.1. Two specially-trained individuals were required to apply the Polyurethane, Estane, or Neoprene shoes. Personnel had to be trained before attempting installation of the shoes. Installation procedures of the Estane kit were less complicated than those of the other two kits.

1.7.2.2. Installation of the Polyurethane shoes required shop facilities equivalent to general support maintenance. The shoes were highly susceptible to contamination from moisture, perspiration of the hands, and cleaning solvents. Humidity-controlled shops and blade racks were required.

1.7.2.3. Installation of the Estane and Neoprene shoes required shelter when the installation was made during windy, dusty, or rainy conditions. When hangars or maintenance tents were not available, a canvas-covered 2 1/2-ton truck was used. Maintenance work stands were required when the truck was not used.

1.7.2.4. Elapsed time to complete installations was as follows:

Polyurethane	Estane	Neoprene
30 hours (including 24 hours curing time)	12 hours (including 8 hours curing time)	16 hours (including 10 hours curing time)

Installation at the organizational level was not deemed practical.

1.7.3. Effect on Flight Characteristics.

1.7.3.1. The Polyurethane, Estane, and Neoprene shoes did not cause adverse flight characteristics when they were properly applied and while they were in a serviceable condition.

1.7.3.2. Vibrations occurred when the shoes were damaged as a result of flying in rain. The vibrations varied in intensity according to the extent of damage to the shoes. Minor damage caused moderate vibrations; extensive damage caused severe vibrations.

1.7.4. Resistance to Erosive Agents (Sand, Rain, and Dust).

1.7.4.1. Polyurethane, Estane, and Neoprene shoes withstood the effects of sand and dust.

1.7.4.2. Flight through rain damaged the Polyurethane, Estane, and Neoprene shoes. Flight through moderate rain resulted in serious damage; flight through heavy rain resulted in destruction of the three types tested.

1.7.4.3. Abrasive wear occurred primarily on the outboard three feet of the shoes. The wear on the inboard three feet of the shoe was negligible.

1.7.5. Environmental Extremes.

Environmental extremes (temperate and desert) encountered during the test had very little noticeable effect on the shoes.

1.7.6. Maintenance Requirements.

1.7.6.1. Very little maintenance was required on properly-installed shoes if rain was not encountered during flight.

1.7.6.2. Damaged shoes must be removed at the direct-support category of maintenance.

1.7.7. Ability To Adhere to the Rotor Blades.

The Polyurethane, Estane, and Neoprene shoes adhered to the rotor blades if rain was not encountered during flight.

1.8. CONCLUSIONS.

1.8.1. The kits tested do not possess a military potential in a temperate or tropic area because of the effects of rain.

1.8.2. Data produced and analyzed indicate a military potential for use in an arid area.

1.8.3. None of these kits is suitable for installation or removal at the organizational level because of the complicated procedures and elapsed time required to complete the operations.

1.8.4. The Estane kit is the most suitable for installation or removal at the direct-support category of maintenance because of the additional time required to install the other kits.

1.9. RECOMMENDATIONS.

It is recommended that:

1.9.1. Research continue until suitable material is found for elimination of the rotor-blade erosion problems in all environments.

1.9.2. Further consideration be given to the Estane kit for Army use only in desert areas provided that:

1.9.2.1. Installation is accomplished at the direct-support maintenance category.

1.9.2.2. Helicopters with the shoes installed are restricted from flying in rain.

1.9.3. Further testing be conducted under controlled test conditions to develop specific data relative to the life-expectancy of the Estane shoe in an arid environment.

SECTION 2

DETAILS AND RESULTS OF SUBTESTS

SECTION 2 - DETAILS AND RESULTS OF SUBTESTS

2.0. INTRODUCTION.

This test was designed to subject these kits to the Army environment and evaluate their capabilities against Army requirements. Testing was conducted at Fort Rucker, Alabama (USAAVNTBD); Fort Bragg, North Carolina (XVIII Airborne Corps); Fort Benning, Georgia; and the Mohave Desert ("Operation Desert Strike"). The erosion preventive shoes were affixed to UH-1B and UH-1D rotor blades. Testing began in March 1964 and was completed in February 1965.

2.1. PHYSICAL CHARACTERISTICS.

2.1.1. Objective.

To determine the test item's physical characteristics.

2.1.2. Method.

Each kit was weighed and measured as appropriate. Features such as material properties and bonding compounds were noted and recorded.

2.1.3. Results.

The physical characteristics of the kits were as follows:

2.1.3.1. Polyurethane.

Kit Weight	Shoe Weight (2 ea.)	Shoe Width	Shoe Length
30 lb.	15 oz.	8 in.	6 ft.

Shoe Thickness

Outboard - 3 ft. 0.060 in. at the center line (leading edge), tapering to 0.010 in. at the trailing edges.

Inboard - 3 ft. 0.030 in. at the center line (leading edge), tapering to 0.010 in. at the trailing edges.

Bonding Compounds

Cement: Epon 934 or Milbond 934 (interchangeable) Parts "A" and "B".

Sealer: N-55

Edge Sealer: N-100-9

Thinner: N-450-11

Storage Life of Compounds

Cements - 3 months; sealers and primers - 6 months

The cements, sealers, and primers deteriorate with heat and require cool storage (not over 72°F.). Detailed contents of the kit are listed in appendix II.

2.1.3.2. Estane.

Kit Weight	Shoe Weight (2 ea.)	Shoe Width	Shoe Length
11 lb.	11 oz.	7 in.	6 ft.

Shoe Thickness

0.050 in. at the center line (leading edge), tapering to 0.010 in. at the trailing edges.

Bonding Compounds

Cement Parts "A" and "B": (Manufacturer Part No.) 72-066-16 and -17.

Sealer: EC-801

Primer Parts "A" and "B": (Manufacturer Part No.) 72-066-14 and -15.

Storage Life of Compounds

Cements - 3 months; sealers and primers - 6 months

The cements, sealers, and primers deteriorate with heat and require cool storage (not over 72°F.). Detailed contents of the kit are listed in appendix II.

2.1.3.3. Neoprene.

Kit Weight	Shoe Weight (2 ea.)	Shoe Width	Shoe Length
12 lb.	13 oz.	7 in.	6 ft.

Shoe Thickness

0.050 in. at the center line (leading edge), tapering to 0.010 in. at the trailing edges.

Bonding Compounds

Cement: (Manufacturer Part No.) 72-066-13

Sealer: (Manufacturer Part No.) 72-066-37

Storage Life of Compounds

Cement - 3 months; sealer - 6 months

The cement and sealer deteriorate with heat and require cool storage (not over 72°F.). Detailed contents of the kit are contained in appendix II.

2.1.4. Analysis.

Not applicable.

2.2. INSTALLATION REQUIREMENTS.

2.2.1. Objective.

To determine the installation requirements.

2.2.2. Method.

As shoes from each kit were installed, the following were noted and recorded: Installation time, complexity, personnel requirements, and facilities required.

2.2.3. Results.

2.2.3.1. Personnel Requirements.

2.2.3.1.1. Polyurethane. Thirty-four Polyurethane kits were used during the test. Eighteen operations were required to complete each installation.

Installation required two mechanics eight man-hours each per kit (a total of 16 man-hours). An elapsed time of 30 hours (includes 24 hours curing time) was required to complete each installation.

Installation required a high skill level. Personnel utilizing only the manufacturer's manual for instruction could not apply the shoes but required direct instructions during the first installation. Strict compliance with all installation procedures was necessary to obtain a satisfactory installation. Blade cleaning and cement operations were critical due to the high susceptibility of the compounds to contamination by moisture. Detailed instructions are contained in appendix III.

2.2.3.1.2. Estane. Eight Estane kits were used during the test. Thirteen operations were required to complete each installation.

Installation required two mechanics four man-hours each per kit (a total of eight man-hours). An elapsed time (includes eight hours curing time) of 12 hours was required to complete the installation.

Although personnel required direct instructions for the first installation, the special training requirements were not as stringent as for the Polyurethane or Neoprene kits. Detailed instructions are contained in appendix III.

2.2.3.1.3. Neoprene. Fifteen Neoprene kits were installed during the test. Twenty operations were required to complete each installation.

Installation required two mechanics six man-hours each per kit (a total of 12 man-hours). An elapsed time (includes ten hours curing time) of 16 hours was required to complete each installation.

Installation of the Neoprene shoes required a high skill level primarily because of the complicated cement activation procedures. Personnel utilizing only the manufacturer's manual could

not apply the shoes but required direct instructions during the first installation. To obtain a satisfactory installation, strict compliance with all installation procedures was necessary during subsequent installations. Detailed installation instructions are contained in appendix III.

2.2.3.2. Facilities Required for Installation of the Kits.

2.2.3.2.1. Polyurethane. Removal of the rotor blades from the helicopter was necessary to apply the Polyurethane shoes. To prevent moisture contamination of the blade surface, dehumidified facilities were required. This was accomplished at Fort Bragg by the use of a paint shop with humidity controls. It was accomplished at Fort Rucker by the use of a heat gun, FSN 4940-357-1369, and by heat lamps, manufacturer's part number A26-13 (no federal stock number). Shoes were applied with and without humidity controls during the test. Unsatisfactory results were obtained from those shoes installed without humidity controls.

Rotor blade stands were required for the installation. Locally-manufactured wooden stands and stand assembly, FSN 1740-508-9814, were used during the test. The locally-manufactured stands were more suitable for the installation of these shoes. They were designed to provide the proper working height and to prevent movement of the blades when pressure was applied during the rolling operation of the installation. Other minor items required for installation were contained in the kit.

2.2.3.2.2. Estane. Removal of the blades from the helicopter was not required to apply the Estane shoes. Shelter was required for the rotor blades during installation under windy and dusty conditions. Hangars were used when available. When hangars were not available, a 2 1/2-ton canvas-covered truck was used (FSN 2320-835-8515). The truck was positioned in front of the helicopter permitting the rotor blade to protrude under the canvas cover. The floor of the truck served as a work platform. Maintenance stands were required for those installations during which a truck was not used. A hydraulic maintenance stand (FSN 1730-390-6618) was used and found to be suitable. Any maintenance stand which provides the proper working height could be utilized. Other minor items required in kit installation were contained in the kit.

2.2.3.2.3. Neoprene. Removal of the rotor blades from the helicopter was not required to apply the Neoprene shoes. Installation facilities were the same as those outlined above for the Estane shoes.

2.2.4. Analysis.

2.2.4.1. Of the three kits tested, the Estane kit was most satisfactory for installation at the direct support level of maintenance because of the excessive time required to install the other kits.

2.2.4.2. Manufacturer's instructions were adequate; however, they were tedious and time-consuming, and installation personnel required previous practical experience.

2.3. FLIGHT CHARACTERISTICS.

2.3.1. Objective.

To determine the effects of the shoe installation on helicopter flight characteristics.

2.3.2. Method.

The shoes were installed on UH-1 type helicopters. The helicopters were flown on normal Army missions, and adverse flight characteristics were reported by flight crews and project personnel.

2.3.3. Results.

2.3.3.1. Adverse flight characteristics were not noted while the shoes were in a serviceable condition.

2.3.3.2. Application of the Polyurethane shoes (accomplished before the blades are installed on the helicopter) required that the rotor blades be balanced before installation on the helicopter and that they be tracked prior to flight. Application of the Estane and Neoprene shoes (accomplished while the blades are on the helicopter) required blade tracking prior to flight. Improper application resulted in vibrations and unsatisfactory flight characteristics (figure 1).

2.3.3.3. Vibrations were encountered in flight when the erosion shoes had been damaged by tree strikes and flying in rain, or when they had separated. Vibration intensity varied according to the amount of damage incurred.

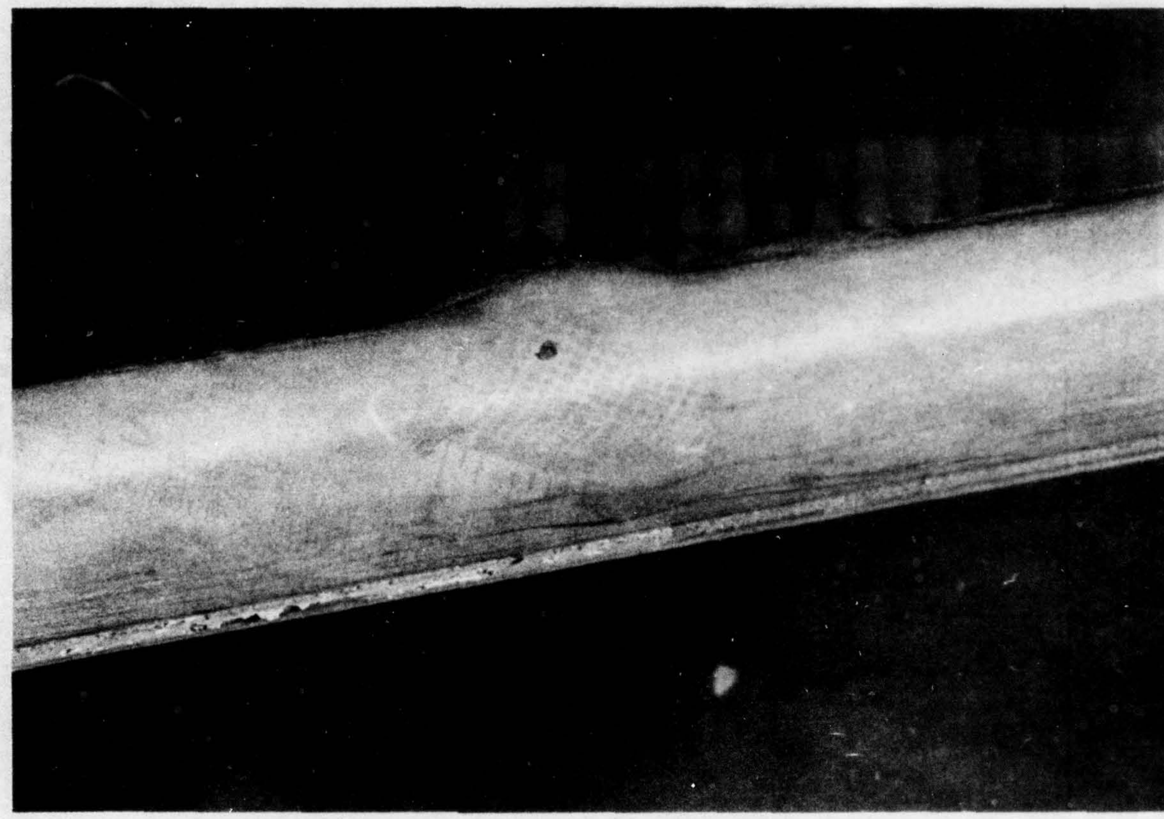

Figure 1. Improperly applied Neoprene shoe after flight

2.3.3.4. Damage such as bubbles and small separations caused moderate vibrations. Extensive damage such as loss of portions of the shoe caused severe vibrations (figure 2).

2.3.4. Analysis.

Not applicable.

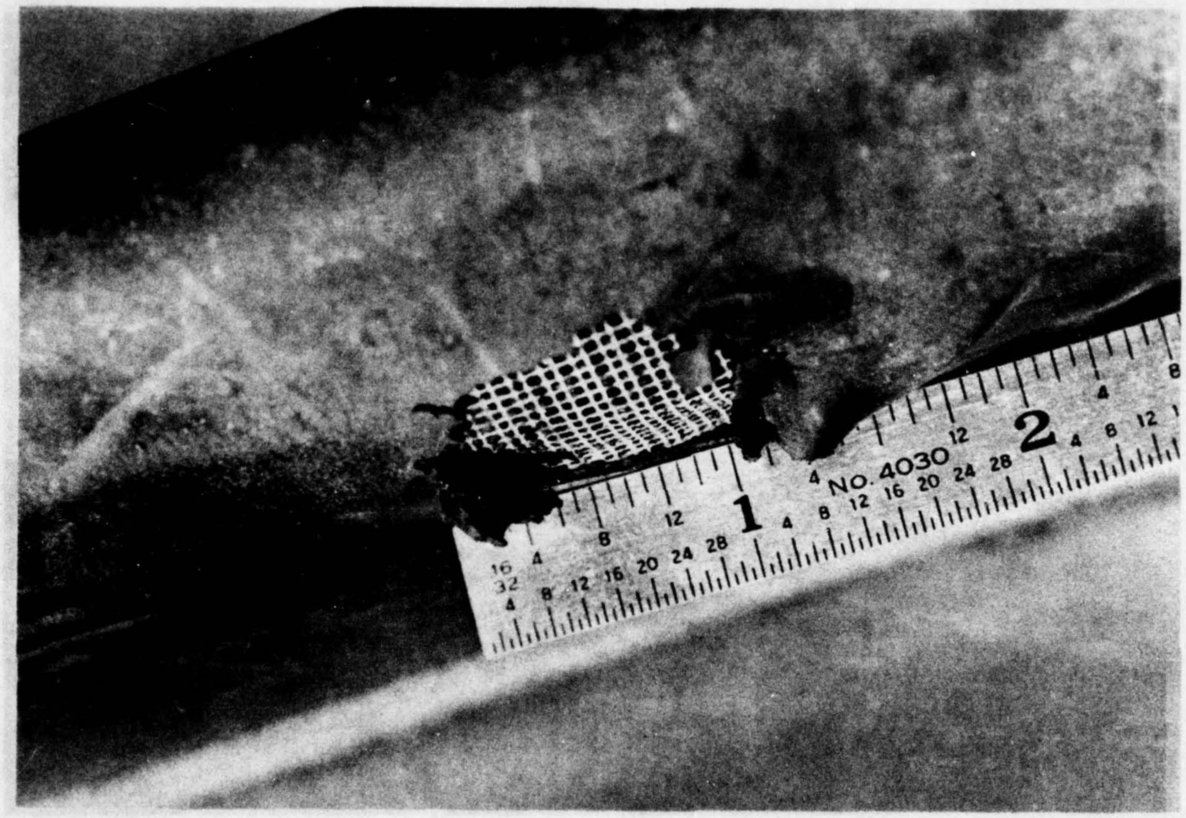

Figure 2. Estane shoe damage resulting from flight in rain.

2.4. <u>RESISTANCE TO EROSIVE AGENTS (SAND, RAIN, AND DUST).</u>

2.4.1. <u>Objective</u>.

To determine the resistance of the shoes to erosive agents (sand, rain, and dust).

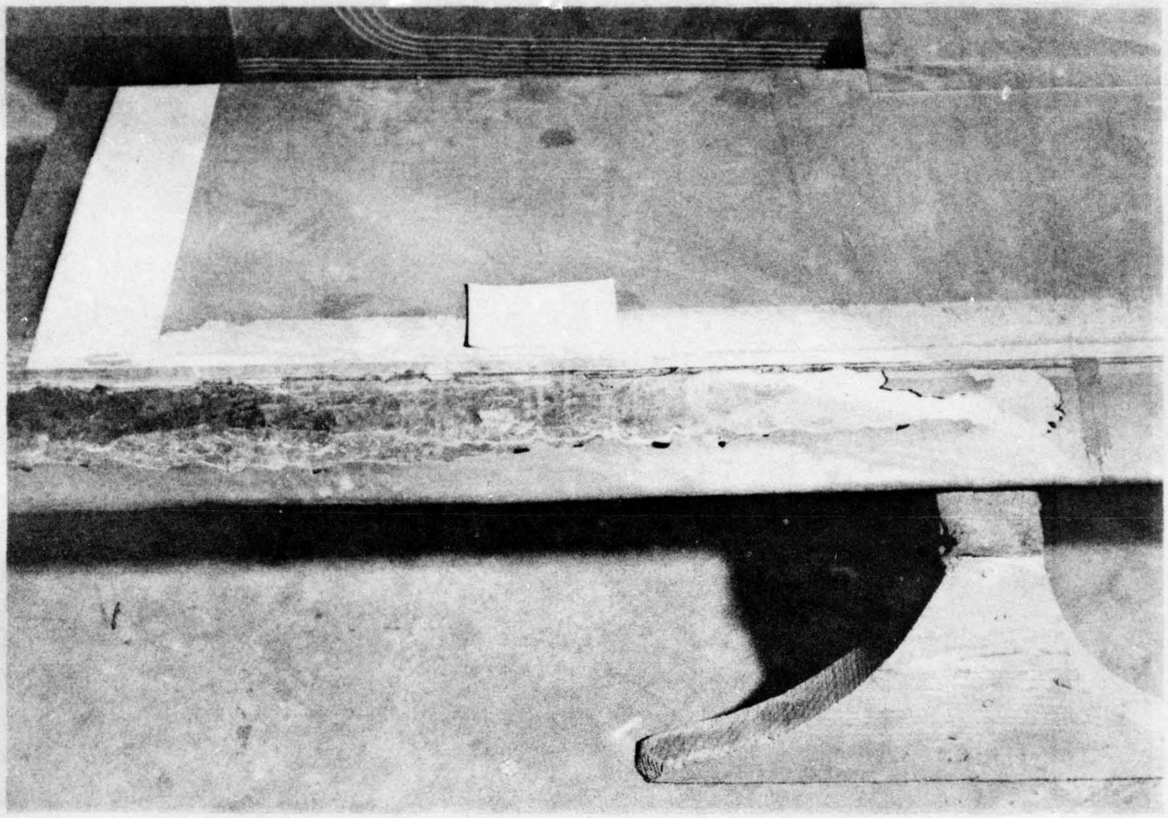

Figure 3. Polyurethane shoe damaged by flight in heavy rain.

2.4.2. Method.

Test shoes were installed on UH-1 type helicopters. The helicopters were flown on normal Army missions. A data card to indicate conditions encountered (sand, dust, and rain), total flight time, and shoe condition (before and after flight) was maintained on each test helicopter.

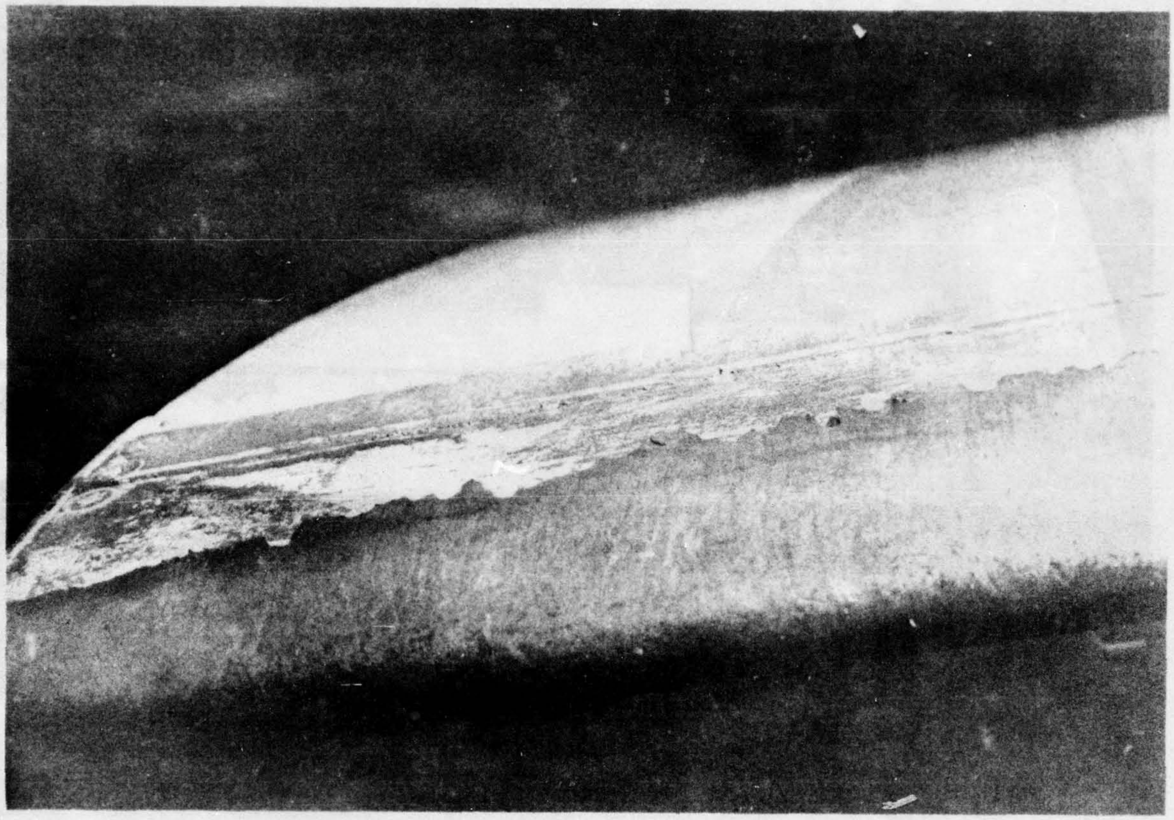

Figure 4. Neoprene shoe damaged by flight in heavy rain.

2.4.3. Results.

2.4.3.1. Sand and Dust.

Damage to the Polyurethane, Estane, and Neoprene from shoe operation in sand and dust was negligible. The damage (or wear) caused by sand and dust consisted of shallow surface abrasions. Because of the elasticity of the material and the effects of the cements on the material, damage could not be measured accurately. It is estimated that the material was worn away at the rate of 0.001 inch per 100 flying hours. The life expectancy in a sand and dust environment was not determined as the shoes were lost from other causes.

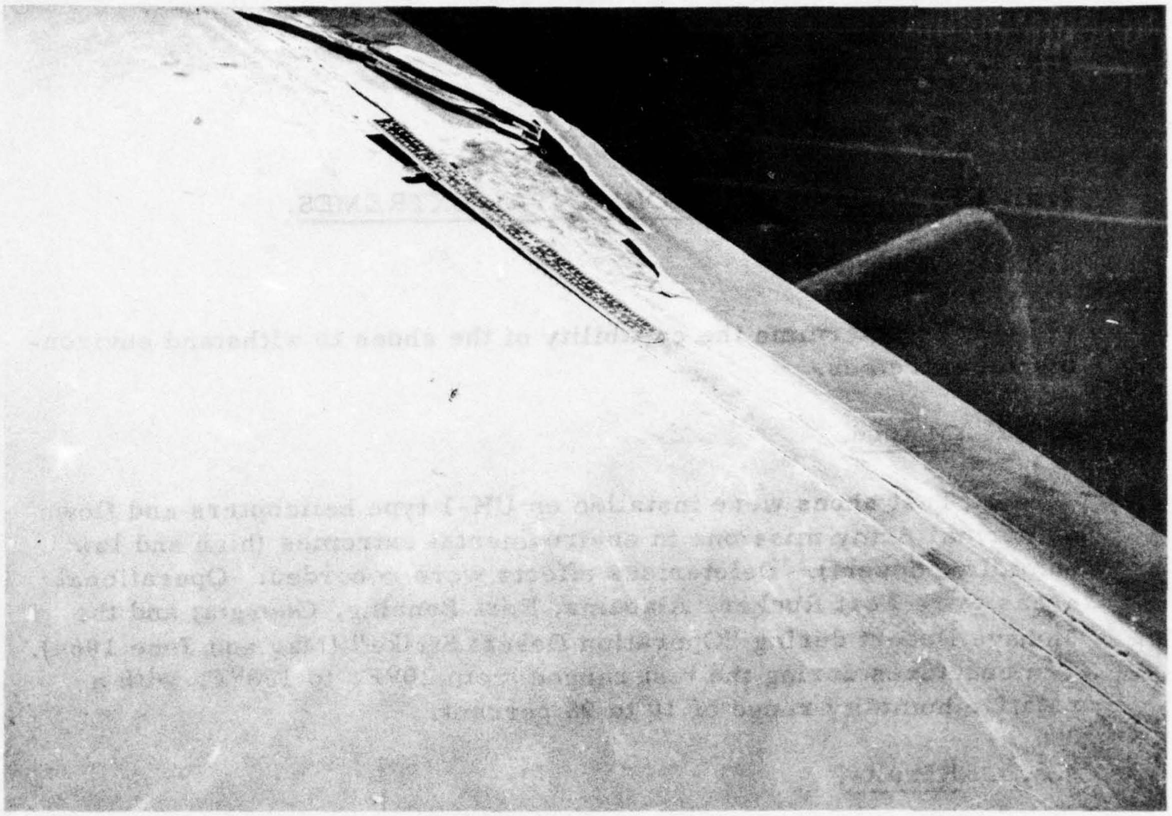

Figure 5. Polyurethane shoe with separation caused by flight in rain.

2.4.3.2. Rain.

Flight through rain was detrimental to Polyurethane, Estane, and Neoprene shoes. Flight through light rain resulted in reparable damage such as bubbles in the surface of the shoes and minor separation of the trailing edges. Flight through moderate rain for short periods of time (5 to 15 minutes) resulted in reparable damage such as bubbles in the surface of the shoes and trailing edge separation. Flight through moderate rain for prolonged periods (one to three hours) caused irreparable damage to the shoes. Flight through heavy rain destroyed the shoes. The maximum flying time accumulated in heavy rain prior to destruction of the shoes was three hours.

2.4.4. Analysis.

Not applicable.

2.5. EFFECTS OF ENVIRONMENTAL EXTREMES.

2.5.1. Objective.

To determine the capability of the shoes to withstand environmental extremes.

2.5.2. Method.

Test shoes were installed on UH-1 type helicopters and flown on normal Army missions in environmental extremes (high and low humidity, desert). Deleterious effects were recorded. Operational areas were Fort Rucker, Alabama; Fort Benning, Georgia; and the Mohave Desert during "Operation Desert Strike" (May and June 1964). Temperatures during the test ranged from 20°F. to 108°F. with a relative humidity range of 10 to 98 percent.

2.5.3. Results.

Temperature and humidity extremes encountered during the test did not noticeably affect the shoes.

2.5.4. Analysis.

Not applicable.

2.6. MAINTENANCE REQUIREMENTS.

2.6.1. Objective.

To determine the shoe maintenance requirements and the ability of the shoes to adhere to the rotor blades.

2.6.2. Method.

Polyurethane, Estane, and Neoprene shoes were installed on UH-1 type helicopters and flown on normal Army missions. All maintenance prior to shoe failure or excessive deterioration was recorded.

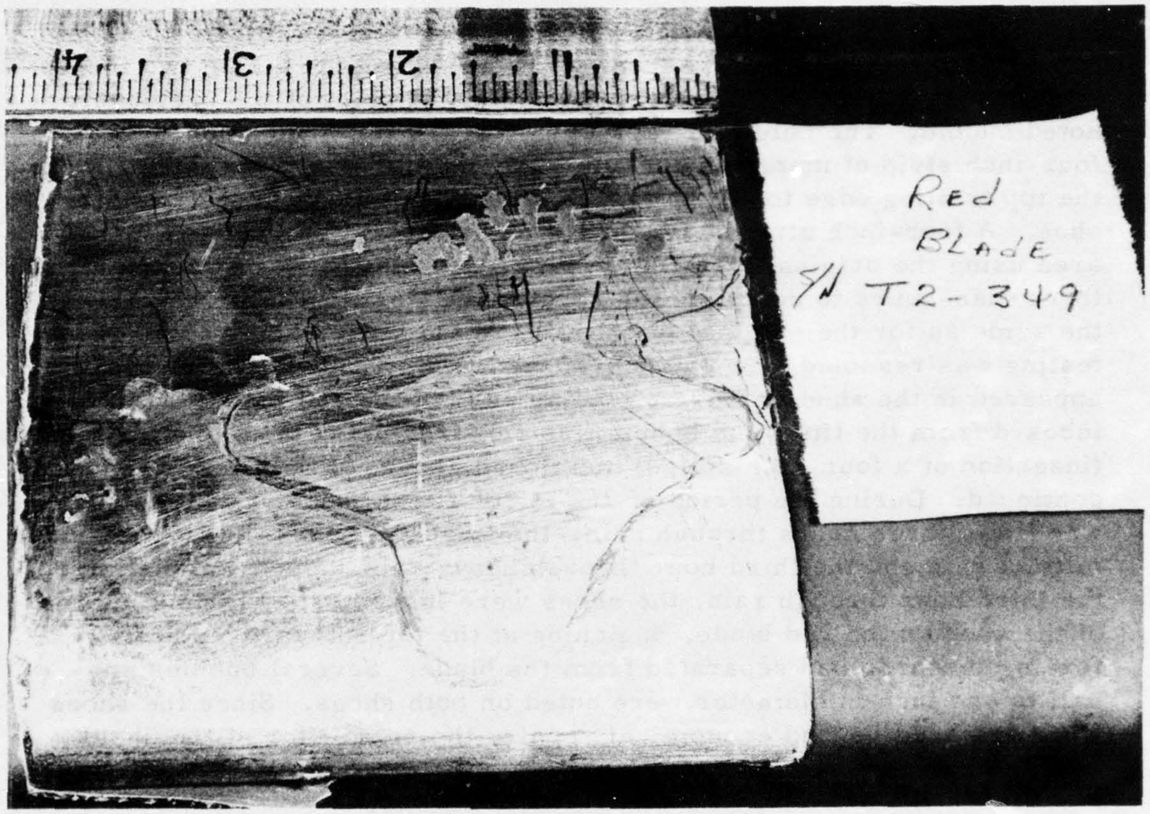

Figure 6. Polyurethane shoe with damaged portion removed to effect repair.

2.6.3. Results.

2.6.3.1. Polyurethane Kits.

2.6.3.1.1. The USAAVNTBD tested three Polyurethane kits in the Fort Rucker area with the following results:

After 60 hours of test flight time on a UH-1D (S/N 60-6034) a bubble, 1 1/2 inches wide, appeared in the shoe on the top leading edge of the white blade, 14 inches inboard from the tip. The cause of the bubble could not be definitely determined. Flight testing was continued to 160 hours test time with no change in the bubble. At

160 hours the helicopter was flown through rain for 30 minutes. Upon completion of the flight, the shoes were inspected and a hole two inches in diameter was found on the white blade at the point of the previously noted bubble. The hole was repaired using the following procedure: A four-inch strip of material (including the defective area) extending from the top trailing edge to the bottom trailing edge was removed from the shoe. A four-inch strip of Polyurethane material was inserted into the area using the original installation procedures. One mechanic required three man-hours to complete the repair. Curing time after repair was the same as for the original installation of the kit (24 hours). Flight testing was resumed. At 250 hours' test time, a bubble two inches wide appeared in the shoe on the top leading edge of the red blade, 18 inches inboard from the tip. The bubble was repaired using the same procedures (insertion of a four-inch splice) mentioned above. Flight testing was continued. During the period of 362 to 365 flight hours, the helicopter was flown three hours through rain: the first two hours through intermittent rain and the third hour through heavy rain. Upon completion of the third hour through rain, the shoes were inspected. Eighteen inches of the shoe on the red blade, beginning at the top outboard tip and extending inboard, had separated from the blade. Several bubbles one-half to one inch in diameter were noted on both shoes. Since the shoes were damaged beyond economical repair, the remainder of the shoes was removed.

A Polyurethane and a Neoprene shoe were applied to opposite blades. The Polyurethane shoe was installed by the manufacturer's representative and the Neoprene shoe by the USAAVNTBD. Humidity controls were not used during the installation, and the relative humidity was 90 percent and the ambient air temperature was 88°F. Six flight test hours after installation, the Neoprene shoe had to be removed due to damage. (Details concerning the Neoprene shoe are contained in paragraph 2.7.3.3.) The Neoprene shoe was replaced with a Polyurethane shoe by the USAAVNTBD. A heat lamp (manufacturer's P/N A26-13) was utilized for the purpose of eliminating moisture during the installation. After completion of the installation, the helicopter was flown an additional 47 hours, of which 12 hours were in rain. Of the 12 hours flown in rain, the first 9 hours were flown in intermittent rain and the last three hours in moderate-to-heavy rain. Upon completion of the last flight of the twelve hours, the rotor blades were inspected. Inspection revealed that the shoe which had been installed without humidity controls had separated for 18 inches from the top outboard tip of the rotor blade. The shoe on the opposite blade which had

been installed using humidity controls was in serviceable condition. Both shoes were removed. The accelerated logistical-evaluation test, which was being conducted on the helicopter, did not permit replacement of the shoe.

The helicopter was later grounded for repairs and Polyurethane shoes were installed. These shoes accumulated 276 flying hours before the blades were removed from the helicopter due to attainment of rotor-blade time between overhaul (1100 hours). Shoe maintenance was not required during the 276 flying hours in which rain was not encountered.

2.6.3.1.2. The XVIII Airborne Corps, Fort Bragg, North Carolina, and the 11th Air Assault Division, Fort Benning, Georgia, tested 31 Polyurethane kits. The USAAVNTBD assisted these organizations with the installation of the kits. The XVIII Corps and the 11th Air Assault Division participated in field exercises (Desert Strike and Project TEAMS) during the time the kits were used. Results of these tests are contained in appendix I.

2.6.3.2. Estane Kits.

2.6.3.2.1. Three Estane kits were tested on UH-1D Helicopters by the USAAVNTBD with results as follows:

On 24 April 1964, Estane shoes were applied to the rotor blades of a UH-1D Helicopter (S/N 60-6032). After 70 flight hours at Fort Rucker, Alabama; Fort Worth, Texas; and Yuma, Arizona, two bubbles one inch in diameter appeared on the white blade shoe. They were located on the top leading edge of the blade 20 inches from the tip. These bubbles were repaired by injecting bonding cement (same as that used for installation) into the bubbles and rolling them down. One mechanic required 30 minutes to complete this repair. Curing time was the same as that required at installation (eight hours). Three flying hours after the repair, the shoes were inspected and the bubbles had returned; the diameter had increased to two inches. The shoe material covering the bubbles was soft and spongy. The shoe on the red blade was in good condition. At this time the helicopter was transferred and the material removed.

On 4 August 1964, Estane shoes were applied to the rotor blades of a UH-1D (S/N 60-6034). After 92 flight hours, of which the

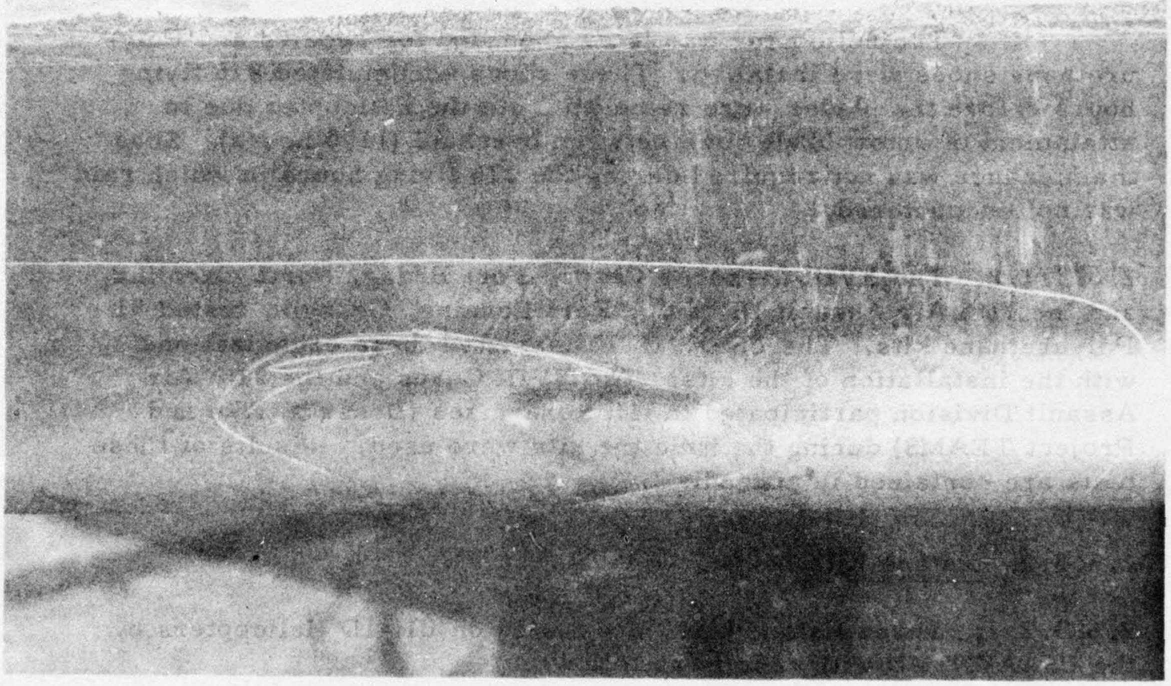

Figure 7. Estane shoe showing bubble.

last three hours were in heavy rain, three bubbles appeared in each shoe. The bubbles were 1 1/2 inches in diameter and located on the top leading edge of the inboard three feet of the shoes. Inspection revealed that water had been forced under the shoes through small nicks in the surface of the material. Since erosion was usually more severe on the outboard three feet of the blade, the inboard three feet of each shoe were removed and the helicopter released for flight. Removal of the inboard three feet of the shoes required two mechanics three man-hours. The first flight after removal of the inboard three feet was of one hour's duration in heavy rain. Upon completion of the flight, the shoes were found to be unserviceable and were removed.

On 15 December 1964, blades with Estane shoes were installed on a UH-1D (S/N 60-6034). Flight time accumulated on these shoes was 226 hours, the last three hours of which were in heavy rain. Upon completion of the flight through heavy rain, the shoes were inspected. Both shoes contained numerous bubbles 2 1/2 inches in diameter on the inboard three feet of the leading edges. The test had been terminated; therefore, the shoes were removed. No maintenance was required during the 226 flying hours.

2.6.3.2.2. Results of tests conducted by the XVIII Airborne Corps and the 11th Air Assault Division are shown in appendix I.

2.6.3.3. Neoprene Kits.

2.6.3.3.1. The USAAVNTBD tested 15 Neoprene kits with results as follows:

On 15 March 1964, Neoprene shoes were applied to the rotor blades of a UH-1B Helicopter (S/N 62-1998). Five flying hours later, a trailing-edge separation occurred on both shoes. The separations were six inches long and 1/4 inch deep and were located one foot from the tip. The separated portion of the shoes and the adjacent blade area were cleaned, re-cemented, and the shoes re-applied. Curing time was 10 hours, the same as that required for initial installation. Twenty flying hours after the repair, the helicopter was transferred to USATRECOM at Yuma, Arizona. The helicopter was later transferred to Fort Monmouth, New Jersey. On 11 March 1965, the USAAVNTBD was contacted by Fort Monmouth personnel concerning separation of the trailing edges of the shoes. The Fort Monmouth personnel were informed as to repair and removal procedures. The shoes had accumulated 278 flying hours as of 11 March 1965.

On 15 March 1964, Neoprene shoes were applied to the rotor blades of a UH-1A Helicopter (S/N 60-6086). Four hours after installation, separation occurred at the trailing edge on top of the white blade. The separation was eight inches long and 1/2 inch deep, and extended from the blade tip inboard. The separated portion of the shoe and the adjacent blade area were cleaned, re-cemented, and the shoe re-applied. One mechanic required 20 minutes to complete the repair. Curing time was 10 hours, the same as that required for initial application. Subsequent to repair, the helicopter was transferred to Fort Bliss, Texas. Fifty flying hours after initial application, the rotor

blades were involved in a high-wind accident that caused irreparable damage to the shoes, and they were removed.

2.6.3.3.2. Results of tests conducted by the XVIII Airborne Corps and the 11th Air Assault Division are contained in appendix I.

2.6.4. Analysis.

2.6.4.1. These protective shoes required very little maintenance unless flown in heavy rain. Maintenance consisted of resealing trailing edges, repair of bubbles, and patching. Removal of the shoes could not be accomplished at the organizational category of maintenance.

2.6.4.2. When properly installed, the Polyurethane, Estane, and Neoprene shoes satisfactorily adhered to the blades except during flight in moderate-to-heavy rain.

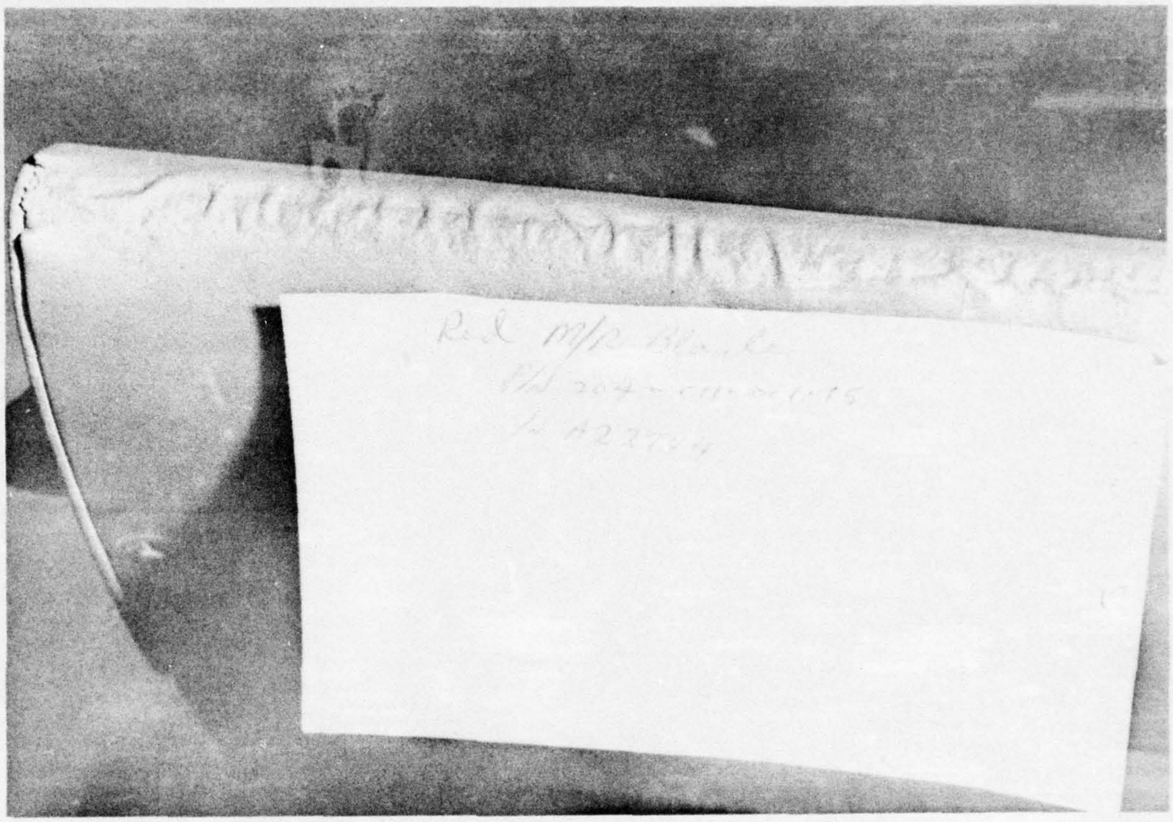

Figure 8. **A** helicopter with the main rotor blades installed was flown 500 hours without the erosion-protective shoes. Subsequently, two sets of shoes have been used on the same set of rotor blades, and the blades have now accumulated over 950 hours. One of these blades is pictured above.

SECTION 3

APPENDICES

APPENDIX I

TEST DATA

A. The following information pertains to kits tested by the 11th Air Assault Division. The 11th Air Assault Division did not attempt to repair the kits. This information was reported to the USAAVNTBD 27 November 1964.

1. Polyurethane Kits.

a. UH-1D (S/N 63-8770): Shoes were in good condition after 54 flight hours.

b. UH-1D (S/N 63-8772): Shoes were removed due to separation after 80 flight hours.

c. UH-1D (S/N 63-8797): Shoes were in good condition after 100 flight hours.

d. UH-1D (S/N 63-8778): Shoes were in good condition after 80 flight hours.

e. UH-1D (S/N 63-12935): Shoes were in good condition after 40 flight hours.

f. UH-1D (S/N 63-8797): Shoes were in good condition after 150 flight hours.

2. Estane Kits.

a. UH-1D (S/N 60-2358): Shoes were removed due to damage caused by the blades striking a tree after 50 flight hours.

b. UH-1D (S/N 63-8674): Shoes were in good condition after 65 flight hours.

c. UH-1D (S/N 63-8749): Shoes were removed due to separation after 40 flight hours.

d. UH-1D (S/N 63-8774): Shoes were in good condition after 223 flight hours.

3. Neoprene Kits.

a. UH-1B (S/N 62-2543): Shoes were in good condition after 70 flight hours.

b. UH-1B (S/N 62-2547): Shoes were in good condition after 65 flight hours.

c. UH-1B (S/N 62-2542): Shoes were in good condition after 50 flight hours.

d. UH-1D (S/N 60-2363): Shoes were in good condition after 15 flight hours.

B. The following information pertains to kits tested by the XVIII Airborne Corps, Fort Bragg, North Carolina. No repairs were attempted by the XVIII Airborne Corps. Subject information was reported as of 30 August 1964.

1. Polyurethane Kits.

a. UH-1B (S/N 61-718): Shoes were in good condition after 42 flight hours.

b. UH-1B (S/N 61-738): Shoes were removed due to separation after 96 flight hours.

c. UH-1B (S/N 61-739): Shoes were removed due to separation after 85 flight hours.

d. UH-1B (S/N 61-740): Shoes were lost due to an aircraft accident after 2 flight hours.

e. UH-1B (S/N 61-742): Shoes were removed due to separation after 14 flight hours.

f. UH-1B (S/N 61-745): Shoes were in good condition after 115 flight hours.

g. UH-1B (S/N 61-746): Shoes were removed due to separation after 111 flight hours.

h. UH-1B (S/N 61-747): Shoes were removed due to separation after 99 flight hours.

i. UH-1B (S/N 61-748): Shoes were in good condition after 51 flight hours.

j. UH-1B (S/N 61-756): Shoes were lost due to an aircraft accident. Time was not recorded.

k. UH-1B (S/N 61-802): Shoes were in good condition after 38 flight hours.

l. UH-1B (S/N 62-12519): Shoes were removed due to separation after 56 flight hours.

m. UH-1B (S/N 62-2520): Shoes were removed due to separation after 97 flight hours.

n. UH-1B (S/N 62-2521): Shoes were removed due to separation after 117 flight hours.

o. UH-1B (S/N 62-2523): Shoes were removed due to an aircraft accident after 60 flight hours.

p. UH-1B (S/N 62-2524): Shoes were removed due to separation after 31 flight hours.

q. UH-1B (S/N 62-2525): Shoes were lost due to an accident after 5 flight hours.

r. UH-1B (S/N 62-2526): Shoes were removed due to an accident after 98 flight hours.

s. UH-1B (S/N 62-2527): Shoes were removed due to separation after 159 flight hours.

t. UH-1B (S/N 62-2532): Shoes were removed due to separation after 14 flight hours.

u. UH-1B (S/N 62-2534): Shoes were removed due to separation after 143 flight hours.

v. UH-1B (S/N 62-2535): Shoes were removed due to separation after 99 flight hours.

w. UH-1B (S/N 62-2536): Shoes were removed due to separation after 84 flight hours.

2. Estane Kits.

a. UH-1B (S/N 61-743): Shoes were removed due to separation after 90 flight hours.

b. UH-1B (S/N 62-801): Shoes were removed due to an aircraft accident. No time was recorded.

3. Neoprene Kits.

a. UH-1D (S/N 60-3583): Shoes were lost due to an accident. No time was recorded.

b. UH-1D (S/N 62-4603): Shoes were removed due to an accident after 80 flight hours.

APPENDIX II

CONTENTS OF THE POLYURETHANE, ESTANE, AND NEOPRENE KITS

A. POLYURETHANE.

1. The following items were included in the Polyurethane Kit:

Item	Quantity
Polyurethane material	2 strips
Tape, paper-covered double-back, 3/8-inch and one-inch wide	1 roll
Tape, clear cellophane, 3/4-inch wide	1 roll
Tape, paper-back masking, one-inch wide	1 roll
Epoxy adhesive, Epon 934 or Milbond 934, Part A and Part B	
NOTE: Adhesive is supplied in quantities for installation and for patching.	
Rollers, rubber, 4-inches wide	
Spreaders, adhesive (serrated edge)	
Gauge, locating aluminum	
Brush, one-inch	1 each
Gloves, white cotton	2 pair
Depressors, wooden tongue	
Sealer, Gates Engineering N-55	

Item	Quantity
Edge sealer and primer, Gates Engineering N-100-9	
Edge sealer thinner, Gates Engineering N-450-11	
Grit paper, No. 80 and No. 320	
Cheese cloth, bleached	1 1/2 pounds
Acetone	1 gallon
Chisels, aluminum or plastic	

2. The following required items would be shop equipment:

Item	Quantity
Heat lamps or hot air blower	
Thermometer, range to 250°F.	1 each
Syringe, hypodermic with No. 20 or larger needle	1 each

3. If the Polyurethane kit is accepted as a standard supply item, items such as tapes, locating gauges, brushes, and acetone could be procured separately through standard supply channels and would preclude duplication in the kits.

4. Items required to assemble the Polyurethane kit were purchased from various sources by the kit manufacturer. No part numbers were furnished.

B. ESTANE. The following items were included in the Estane Kit:

Item	Quantity	Mfg. Part No.
Shoe, erosion	2 each	72-066-8
Primer, Part A	1/2 pint	72-066-14

Item	Quantity	Mfg. Part No.
Primer, Part B	1/2 pint	72-066-15
Cement, Part A	1 pint	72-066-16
Cement, Part B	1 bottle	72-066-17
Installation Procedure Manual	1 each	72-066-21
Paint brush, 1/2-inch	2 each	72-066-26
Cup, cement mix, 8 oz.	5 each	72-066-27
Stick, cement stir	5 each	72-066-28
Gauge, plastic marking	1 each	72-066-29
Tape, masking	2 rolls	72-066-30
Needle and syringe, hypodermic	1 each	72-066-31
Stitcher, steel, 1/8-inch	1 each	72-066-34
Cheese cloth	7 linear yards	72-066-35
Methyl Ethyl Ketone (MEK)	1 quart	72-066-36
Sealer, EC-801	1-3 1/2 oz.	72-066-37
Cotton cloth, lintless	1 linear yard	72-066-38
Applicator, sealant	2 each	72-066-39
Roller, rubber	1 each	72-066-43
Thinner, cement (ethyl acetate)	1/2 pint	
Sandpaper, grit, 180-220	2 sheets	72-066-45

C. NEOPRENE. The following items were included in the Neoprene Kit:

Item	Quantity	Mfg. Part No.
Shoe, erosion, 4-1844	2 each	72-066-2
Cement, B. F. Goodrich A-1209-B	1 pint	72-066-13
Paint brush, 1 1/2 inch	2 each	72-066-26
Stick, cement stirring	3 each	72-066-28
Needle and syringe, hypodermic	1 each	72-066-31
Installation Procedure Pamphlet	1 each	72-066-22
Gauge, plastic marking	1 each	72-066-29
Tape, masking	2 rolls	72-066-30
Toluol	2 1/2 pints	72-066-32
Stitcher, steel	1 each	72-066-34
Cheese cloth	8 linear yards	72-066-35
Methyl Ethyl Ketone (MEK)	1 quart	72-066-36
Sealer, EC-801	1-3 1/2 ounces	72-066-37
Cotton cloth	2 linear yards	72-066-38
Applicator, sealant	1 each	72-066-39
Scraper, Masonite	1 each	72-066-40
Turco 388	1 quart	72-066-41

APPENDIX III

A. INSTALLATION AND REMOVAL PROCEDURES FOR THE POLYURETHANE KIT.

1. Installation.

a. Using a locating gauge and a soft pencil, mark off the installation area on the blade.

CAUTION: Never use a sharp, hard instrument, such as a scribe, on the blade as a scratch in the metal will cause a loss in strength.

b. Locating the masking tape inboard and on the trailing edge side of the guide lines, mask off the installation area.

c. Using gauze moistened with acetone, remove the paint from the rotor blade. If the blade has been flown and shows erosion or corrosion on its leading edge or the prime undercoating paint layers cannot be removed with acetone, sand the surface, in a spanwise direction only, first with No. 80 grit paper and finish sanding to remove scratches with No. 320 or finer grit paper. The blade surface is considered free of paint when there is no trace of paints, primers, or dirt on a clean, white, acetone-moistened gauze pad which has been wiped over the erosion protection area of the blade.

d. Remove the paper and masking tape. Using the locating gauge, mark off the location of the erosion protection system within the prepared area.

e. Apply double-back and paper-back masking tapes to the blade as outlined in the marked area.

f. Position the erosion protection system on the blade with the shiny side out and the thick end butting against the edge of the tip cover. Remove the paper backing from the 3/8-inch double-back masking tape. Using clear cellophane tape, attach the erosion protection system to the 3/8-inch double-back tape.

g. Using clear cellophane tape, attach the starched cloth to the Polyurethane erosion protection system.

h. Fold the Polyurethane erosion protection system back along the olive drab side of the rotor blade.

> NOTE: From this operation until the urethane protection system is adhesive bonded in place, white cotton gloves must be worn because oil from the hands or any other source can destroy the strength of the adhesive.

i. Clean the blade surface and the dull side of the urethane erosion protection system with an acetone-moistened, clean gauze pad followed by a dry, clean gauze pad. The dry pad should pick up the acetone from the surface before it evaporates. The surface is considered clean when there is no trace of dirt visible on a clean, white, acetone-moistened gauze pad which has been wiped over the entire bonding surface.

> NOTE: Operations from this point are limited by the working life of the adhesive. The time period from mixing the adhesive to bonding the erosion protection system in place must not exceed 30 minutes.

j. Pour all of the can of amine hardener, Part B, into the can of epoxy resin labeled Part A. Mix the adhesive completely using the wooden stirrer.

k. Apply the mixed adhesive to the metal surface of the blade using the stirrer. If some adhesive falls on the dull side of the urethane it is not harmful, but the urethane surface should not be coated with adhesive.

l. Score the adhesive using the saw-tooth serrated plastic spreader. Start the spreader at the protection system trailing edge on the olive drab side of the rotor blades. Move the spreader over the leading edge, finishing on the paper masking tape on the black side of the blade.

m. Place the urethane erosion protection system over the leading edge. With both men starting on the olive drab side of the rotor blade at the trailing edge of the urethane center splice, roll out the entrapped air. Push the roller from the trailing edge toward the leading edge. One man works from the center splice to the inboard end;

the other to the tip end. After the olive drab side is completed, continue the operation on the blade side, pushing the roller from the leading edge toward the trailing edge. Force the excess adhesive under the starched cloth and over the masking tape. DO NOT STRETCH THE URETHANE OVER THE MASKING TAPE.

n. Attach the starched cloth to the double-back tape after the rolling is complete. If the work is done outdoors, one-inch wide masking tape should be used to hold the starched cloth to the double-back tape.

o. After the adhesive becomes tacky (the condition of cement when it feels sticky but will not pull loose when touched with the finger), in approximately one-half hour, remove the masking tape. Do not forget the clear cellophane tape at the splice. In the event adhesive squeeze-out has penetrated the masking, it must be removed with acetone or by sanding with No. 320 or finer grit paper. The excess adhesive may be smoothed by wiping with an acetone-moistened gauze pad after it becomes tacky but has not fully hardened.

p. There should be approximately one-half inch of exposed metal surface between the urethane and the paint. After the adhesive has hardened three to four hours, place one-inch wide masking tape on the urethane and over the paint, letting the exposed metal show. Also mask the splice (a one-half inch gap is sufficient) and the inboard and outboard tip ends.

q. Clean the area where the edge sealant will be applied with a clean gauze pad moistened with acetone. Apply one brush coat of GACO N-100-9 primer, permit it to dry 15-20 minutes, and apply the second coat of primer. Permit the second coat of primer to air dry 60-70 minutes. Apply at least six brush coats of GACO N-55 black liquid over the primer allowing at least 15 minutes but not more than one hour between each brush coat. The black liquid should not extend beyond the primed area. The N-55 may be thinned with N-450-11 up to 10 percent by volume. Jelled N-55 shall not be used.

r. After the sealant has dried and the adhesive has hardened for at least 24 hours, remove the masking tape. The blade may be returned to service after the adhesive has had a total of 24 hours of hardening.

2. Removal:

a. Attach a thermometer to the blade using one-inch wide masking tape.

b. Apply heat lamps or hot-air blowers until the blade reaches 185°F. to 200°F. DO NOT EXCEED 200°F. Do not concentrate heat in one spot; a cap separation could occur.

c. While the surface is hot, remove the urethane, using an aluminum or plastic chisel. If the adhesive remains on the metal surface of the blade, reheat and remove it with the aid of an aluminum or plastic chisel.

NOTE: Kit may be removed with plastic or aluminum chisels and acetone without heat.

d. Small amounts of adhesive may be removed by sanding with No. 320 or finer grit paper.

e. Mask the painted areas of the blade using one-inch wide masking tape and paper.

f. The edge sealer may be removed by wiping with an acetone-moistened gauze pad.

g. Remove the masking tape and paper.

h. If the reason for removal is an erosion protection system replacement, the systems shall be replaced in equal weight pairs on opposing rotor blades.

B. INSTALLATION AND REMOVAL PROCEDURES FOR THE ESTANE KIT.

1. Installation.

a. Using a ball-point pen and the plastic marking gauge, mark the edge of the cement area of both the upper and lower sides of the blade. Measure and mark one inch past the inboard end of shoe.

NOTE: Do not use a sharp instrument such as a scribe.

b. Mask the area which will contain the shoe.

c. Using a methyl ethyl ketone (MEK) and cheese cloth swabs, remove all paint within masked area. Use sandpaper to remove primer in same area. After final sanding operation, wash surface with MEK, using a clean, lint-free cotton cloth to wipe MEK from blade before evaporation occurs. Perform cleaning operation at least twice.

d. Thoroughly mix primer Part A and Part B, using equal parts by volume in the paper cup provided in the kit. Be sure Part A is thoroughly mixed before combining the two components. To insure proper mixing, pour from can to paper cup three times. Mixed pot life is eight hours.

e. Apply one coat of mixed primer to metal surface only. *Allow to dry a minimum of one hour. Store brushes in MEK when not in use.*

f. Using a clean, lint-free cotton cloth moistened with MEK, clean the cement side of the shoe. Cloth should be wet but not dripping, as excessive MEK will attack the Estane material.

g. Thoroughly mix cement in a ratio of 15 parts of Part A to 1 part of Part B by volume.

CAUTION: Part B is moisture sensitive and care should be exercised to avoid moisture at the time of mixing. To insure proper mixing, pour from can to paper cup three times.

NOTE: For better application consistency, use three parts mixed cement to one part ethyl acetate solvent.

h. Using a ball-point pen and plastic marking gauge, mark the center line of airfoil (leading edge).

i. Apply one coat of mixed cement to the cement side of shoe and one coat to primed surface of blade. Cement must cover all surfaces. When areas of blade or shoe are void of cement, reapply cement over the area to a uniform coverage. Inspect to insure all areas of the blade and shoe are completely covered with cement.

j. Allow cement to dry 10 minutes.

k. Starting with the outboard end, fold the shoe back on itself and adjust until center lines coincide. Roll down on leading edge only, eliminating trapped air. After contact has been made, no attempt should be made to relocate the shoe. All rolling shall be accomplished in an outboard, inboard direction. Avoid twisting or creasing the erosion shoe. Rubber roll the entire shoe firmly and stitch the edges. When wrinkles occur, they can be rolled out by carefully maneuvering the 1/8-inch steel stitcher in such a manner as to cramp the excess material back into the bonded area and, thus, prevent an overlap.

l. Inspect the entire shoe for trapped air and adequate adhesion. Remove air blister (trapped air) by inserting hypodermic needle into edge of blister farthest from leading edge and inserting toward leading edge, holding needle at a 45-degree angle (or less) from blade surface. Use finger to apply pressure on blister to remove trapped air. Re-roll using steel roller; stitch all edges firmly in place using 1/8-inch steel stitcher.

m. Mask and apply a filler of EC-801 to the outboard, inboard, and aft edges of shoe. Mix EC-801 in proportions supplied. Mix in small quantities as the useful pot life is relatively short. Using the sealant applicator, spatula the fillet in place. Apply the EC-801 in a slightly greater thickness than the shoe. MEK may be used to thin the EC-801 slightly if necessary. Demask immediately after application and a neat fillet of EC-801 should remain. To obtain minimum adhesion required for flying, permit 8 hours' drying time at 60^{o}F. - 80^{o}F.

2. Removal.

a. Mask off blade area adjacent to the erosion shoes (to prevent damage to painted blade area).

b. Rough up erosion shoe surface area with a wire brush or plastic chisel.

c. Apply Turco to roughed-up area of erosion shoe and allow to set for approximately 20 minutes.

d. Scrape erosion shoe off the blade.

e. Repeat the above steps until shoe is removed.

f. Thoroughly clean the blade surface with soap and water or cleaning solvent.

WARNING: Turco 388 is not safe for use on magnesium surfaces. Exercise caution as outlined on the Turco label during use. Wear plastic gloves when working with Turco.

C. <u>INSTALLATION AND REMOVAL PROCEDURES FOR NEOPRENE KIT.</u>

1. <u>Installation.</u>

a. Ambient temperature for installation should be between 40°F. and 110°F. Longer drying time of the cement coats may be required if the humidity approaches 99 percent.

b. Using a ball-point pen and the plastic marking gauge, mark the edge of the cement area on both the upper and lower sides of the airfoil. Measure and mark one inch past the inboard edge of shoe.

c. Remove all paint and loose primer inside the masked area.

NOTE: (a) Turco 388 is not safe to use on magnesium surfaces.

(b) Exercise caution as outlined on the Turco 388 bottle label during its use.

(c) Wear plastic gloves when working with Turco.

NOTE: Sandpaper and acetone may be used in lieu of Turco.

Brush-apply Turco 388 generously to the masked area. Allow sufficient time for paint to soften or be lifted. Usually 15 to 20 minutes is required for reaction to take place. Scrape off residue using the Masonite scraper. Wash remaining tacky (the condition of cement when it feels sticky but will not pull loose when touched with the finger) residue off with a cloth saturated with methyl ethyl ketone (MEK). Wash a second time with a clean cloth saturated with MEK. Dry with a clean cloth while MEK is moist. In the event the masked area contains loose primer or anything which might contribute to a defective bond, repeat cleaning procedure until clean bonding surface is obtained.

d. Use clean cotton cloths moistened with MEK for cleaning the masked area of the blade to be cemented. MEK is to be wiped off while still wet using a clean cotton cloth after the final cleaning operation.

e. Using the plastic marking gauge and the ball-point pen, mark the center line of the airfoil.

f. To prevent sticking, the erosion shoes are normally dusted before packing. This dust should be washed off the surface marked "cement side" with a clean cloth moistened with Toluol. Change cloths frequently to avoid contamination of the washed areas. Clean the entire back (rough) surface in this manner at least twice.

g. Thoroughly stir the cement before using. Apply one even brush coat to both the "cement side" surface of the erosion shoe and the helicopter blade surface to be covered with the erosion shoe.

h. Allow first coat to air dry for a minimum of 30 minutes. If temperature is below 50°F., allow cement to dry at least one hour. Apply a second coat of cement to both surfaces. Allow cement to dry thoroughly for at least one-half hour. If time permits, one hour is the preferred drying time. The cement must be applied evenly on both surfaces to insure that the outside surface will be smooth after installation. Blade and erosion shoe may be cemented up to a maximum of 48 hours before actual installation <u>if cemented parts are covered and kept clean</u>.

i. After the cement is dry, position the shoe on the blade with the two cemented surfaces against each other. The two surfaces will not stick if they are too dry. With the shoe positioned on the blade, move it around until the reference line coincides with the center line of the leading edge.

j. Fold the erosion shoe back on itself, being careful not to move it with respect to the blade.

k. Using a clean, lint-free cloth (hereafter referred to as "tack cloth"), thoroughly moistened with Toluol, activate the cement along the center line of the shoe. The cloth should not be dripping with Toluol. Activate not more than 18 inches to 24 inches of the cemented area on both the blade and the erosion shoe leading edge center line. Avoid excessive rubbing which could remove cement from surfaces.

l. After cement loses "webbiness" and becomes tacky, use rubber roller if available, otherwise use tack cloth slightly moistened with Toluol and roll or sweep activated part of shoe firmly against the leading edge of the blade only. Care must be exercised to prevent trapping air between shoe and blade. Match the reference lines as the shoe is rolled or pressed in place. Avoid stretching the shoes or difficulty will be encountered along trailing edges. The correct method of sweep is from center spanwise toward ends with hand placed diagonally on surface angling away from direction of sweep. When cementing, activating, and rolling or sweeping the erosion shoe on the blade, first work the leading edge down along the entire length and then each side can be activated and swept or rolled down separately. Avoid twisting or sharp creasing of the erosion shoe or cement may be pulled loose from blade or shoe.

m. In the event it becomes necessary to remove or loosen installed shoe, use Toluol to soften adhesion line. A minimum amount of this solvent should be applied to the parting line while slight tension is applied to the shoe. In peeling back the erosion shoe, removal should be slow enough to allow the solvent to separate the interface of the cement coats. If the cement is pulled loose from either the blade or the shoe, the area should be re-cemented.

n. With the loose part of the erosion shoe rolled back, activate a section adjacent to the bonded area using the same procedure as before.

o. When the cement has reached the right state of tack, sweep the next section of the shoe down.

p. Continue in this manner until the erosion shoe is completely installed, then sweep the entire surface using the tack cloth moistened with Toluol, or roll with rubber roller if available.

q. If an air pocket or blister is formed, insert a hypodermic needle into the pocket farthest from the leading edge and inserting toward the leading edge at a 45-degree angle (or less) from the blade surface and press blister to remove air.

r. Inspect the tapered edge to see that it is firmly cemented all around. A wavy condition results if the tack cloth is too moist with solvent. Permit the tackified A-1209-B to dry to the point that enough tack is present to hold edge in place and firmly press or sweep shoe to blade. Stitch all edges using the roller supplied in the kit.

s. After cement is dried, remove masking tape and clean excess cement from blade with MEK. Caution must be exercised to prevent solution from running under and loosening edges of shoe; therefore, wiping direction should be from leading edge toward trailing edge.

t. Mask and apply EC-801 fillet to the outboard, inboard, and aft edges of the shoe. Mix EC-801 in the proportions as supplied. Mix in small quantities as the useful pot life is relatively short. Using the sealant applicator, spatula the fillet in place. Apply the EC-801 in a thickness slightly greater than that of the shoe. Demask and a neat fillet of EC-801 should remain.

2. <u>Removal.</u>

a. Mask off rotor blade area adjacent to the erosion shoe area (to prevent damage to painted blade surface).

b. If some portion of the shoe is not separated, scrape a portion away from the blade.

c. Pull on the separated portion of the erosion shoe and apply a Toluol-soaked cloth between the erosion shoe and blade surface. Continue this procedure until entire shoe is removed.

d. Clean blade area from which shoe was removed with soap and water, methyl ethyl ketone, or acetone.

APPENDIX IV

COORDINATION

This report was coordinated with the following agencies:

US Army Aviation School

US Army Combat Developments Command
Aviation Agency

APPENDIX V

DISTRIBUTION LIST

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AD________________________Accession No.________________________

US Army Aviation Test Board, Ft. Rucker, Alabama. Report of USATECOM Project No. 4-3-5220-02, Military Potential Test of the Helicopter Rotor Blade Erosion-Preventive Kits, 3 June 1965. DA Project No. 1R179191-D-684. 56 pp., 8 illus. Unclassified.

The Polyurethane, Neoprene, and Estane shoes were applied on the main rotor blades of UH-1 helicopters operated at Ft. Benning, Ga., Ft. Rucker, Ala., and "Operation Desert Strike." It was concluded that, because of the effects of rain on the shoes, none of the kits possess military potential for use in tropic and temperate areas; however, data indicate that they possess military potential in arid areas. None of the kits is suitable for installation or removal at the organizational level, and the Estane kit is the most suitable for installation or removal at the direct-support maintenance category. It was recommended that research continue until suitable material is found for the elimination of the rotor-blade erosive problems in all environments; that further consideration be given to the Estane kit for Army use only in desert areas provided that installation is accomplished at the direct-support maintenance category and that helicopters with the shoes installed are restricted from flying in rain; and that further testing be conducted under controlled conditions to develop specific data relative to the life expectancy of the Estane shoes in an arid environment.

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